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(54) **FUEL REFORMER**

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(58) **Field of Classification Search** 422/188–191, 422/193, 198, 200, 213; 423/648.1; 429/19
See application file for complete search history.

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(57) **ABSTRACT**

A fuel reformer including a first pipe, a second pipe which is disposed in the first pipe, a main heat source, which includes an oxidation catalyst, filling the second pipe adapted to generate thermal energy with a predetermined temperature range through an oxidation reaction of a fuel using the oxidation catalyst; an auxiliary heat source which includes a torch connected to the second pipe to ignite and burn the gaseous fuel, thereby preheating the oxidation catalyst to within a reaction starting temperature range, and a reforming reaction unit which includes a reforming catalyst filling a space between the first and second pipes to generate a reforming gas containing hydrogen through the reforming reaction of the fuel using the reforming catalyst by using the thermal energy generated by the main heat source.

14 Claims, 8 Drawing Sheets

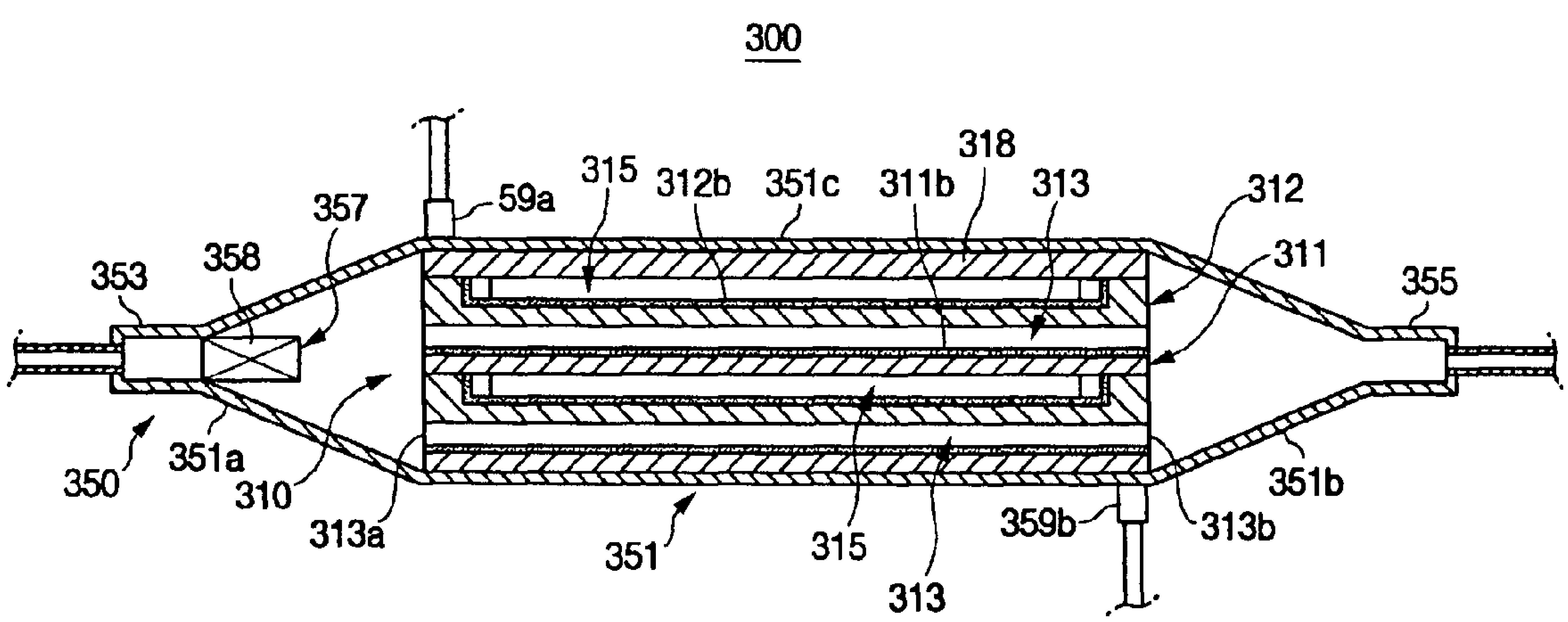

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FIG. 1

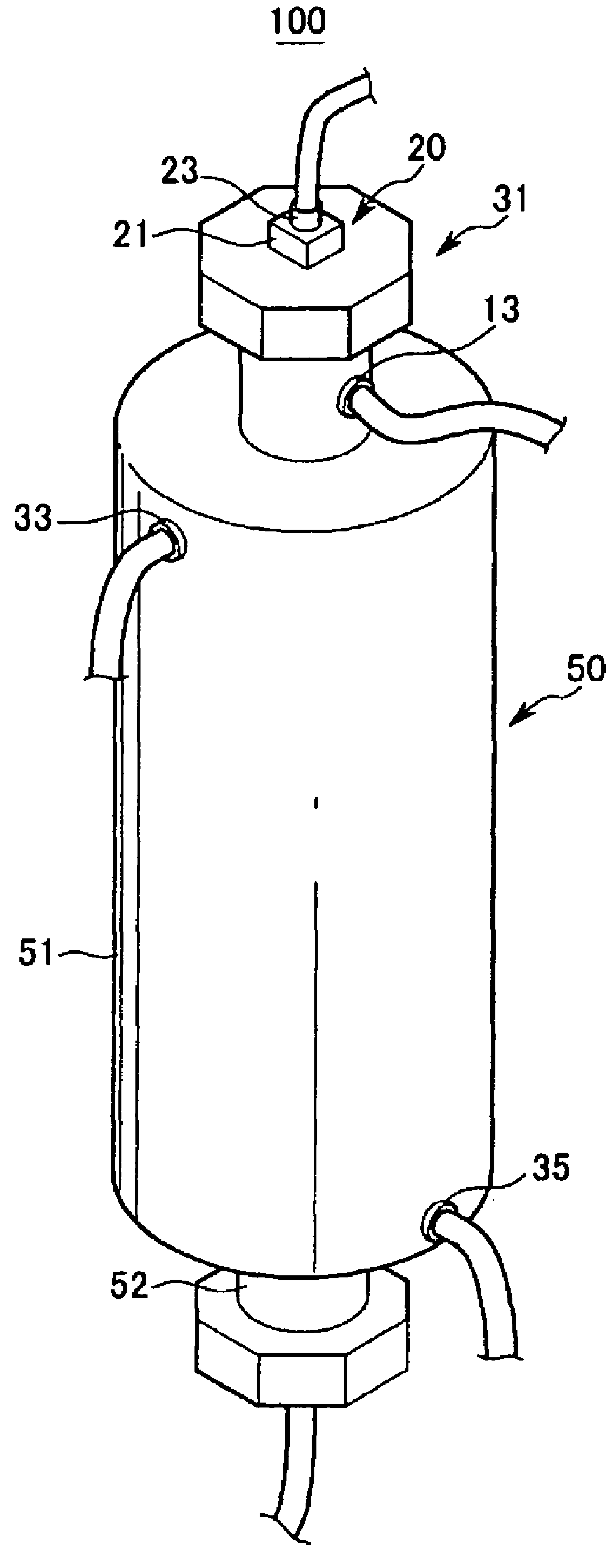


FIG. 2

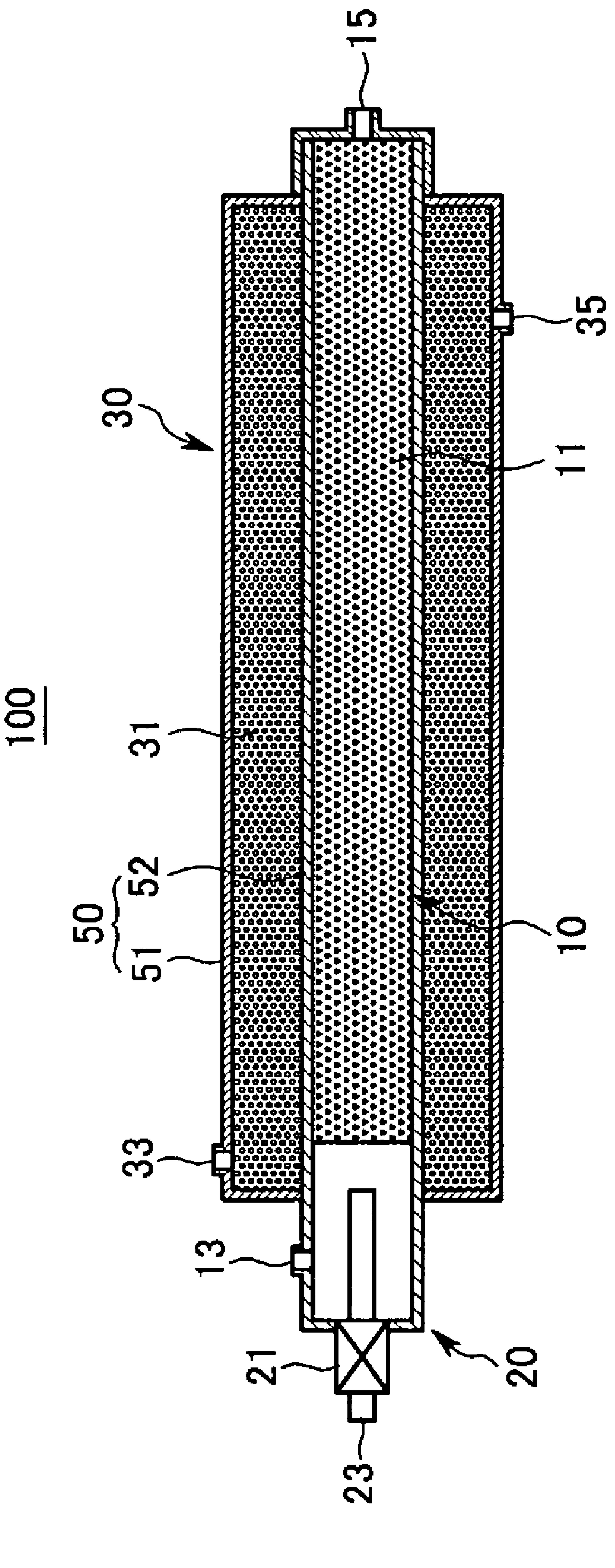


FIG. 3

200

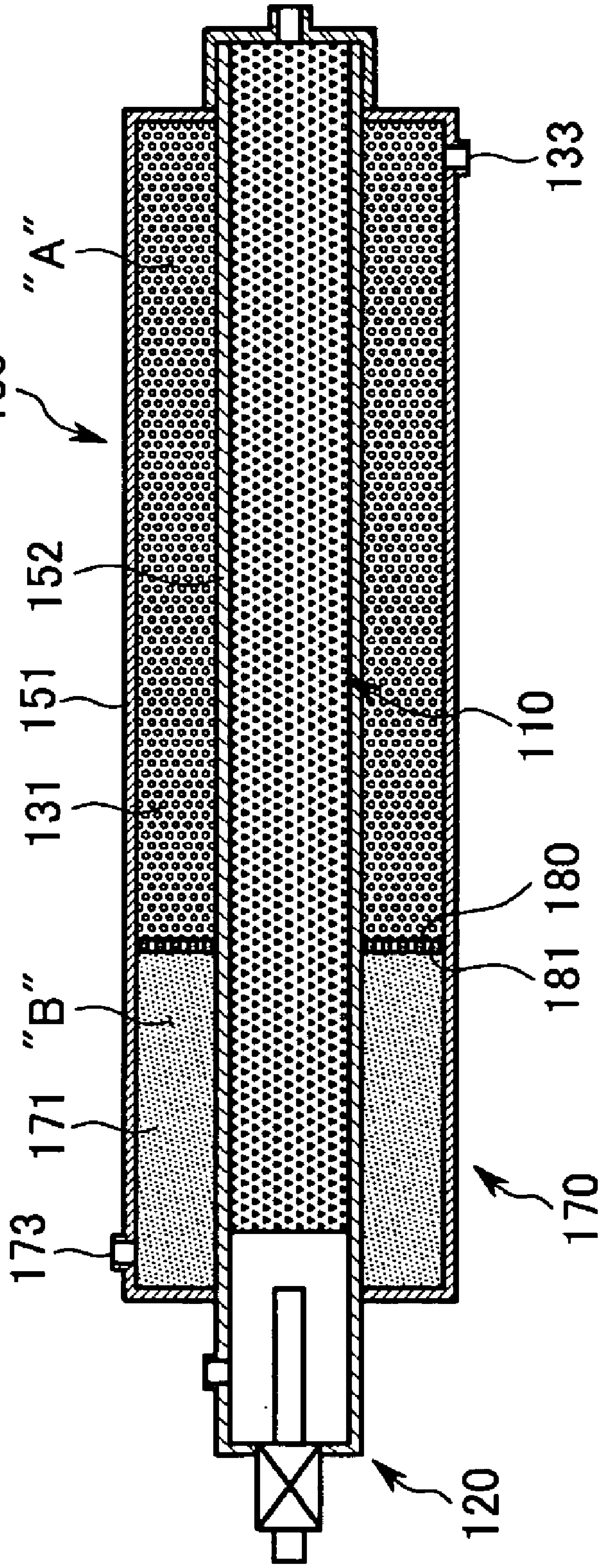


FIG. 4

300

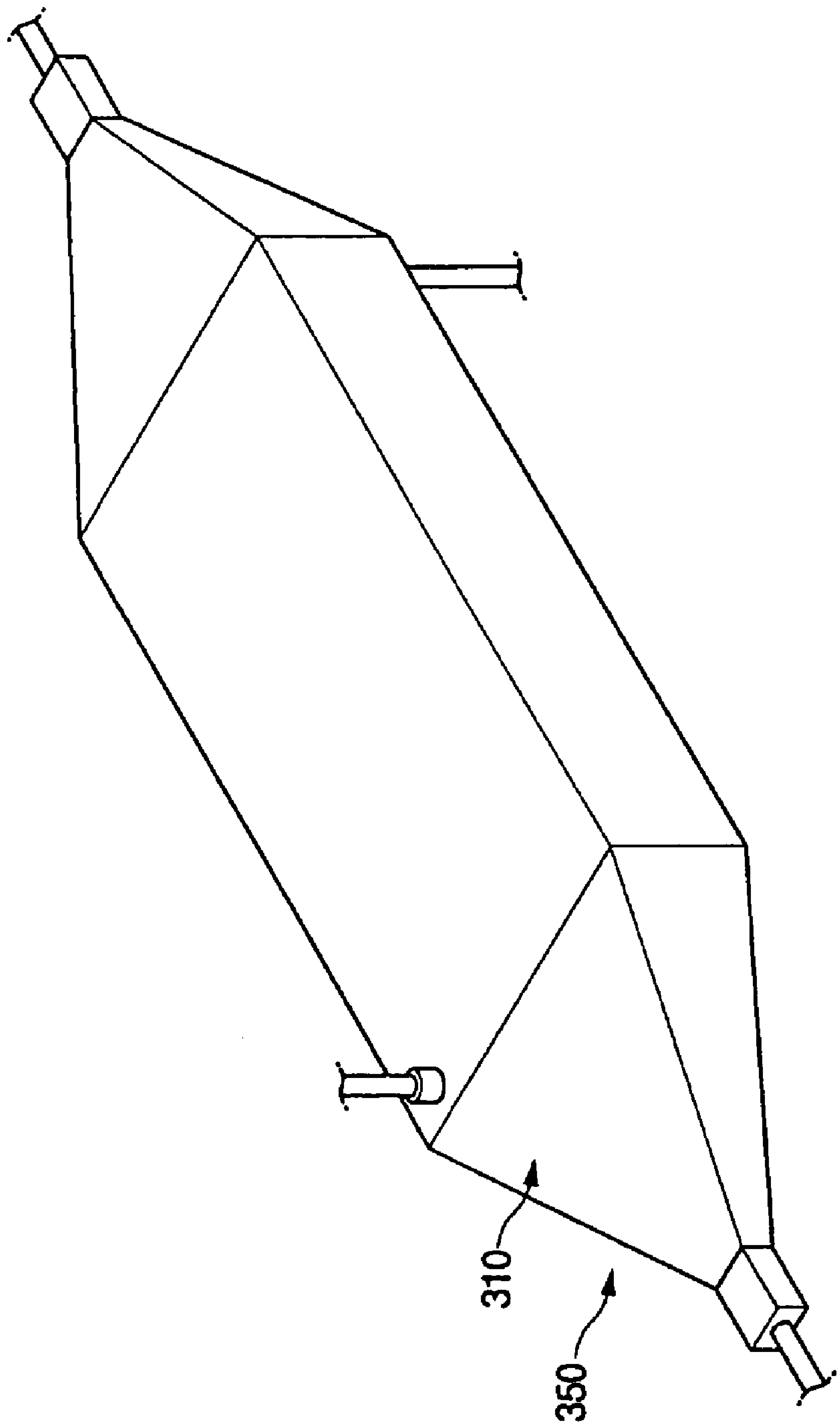


FIG. 5

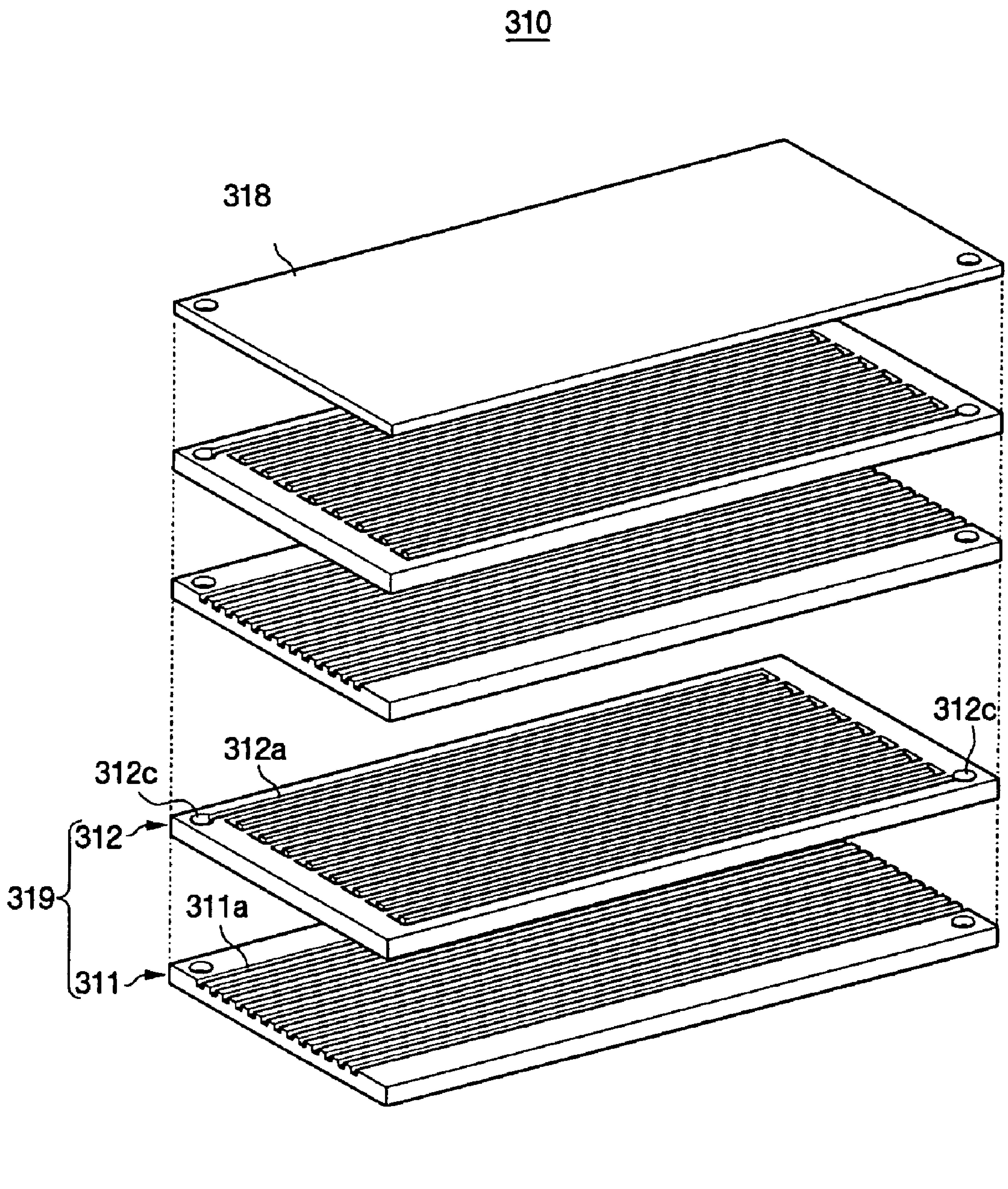


FIG. 6

310

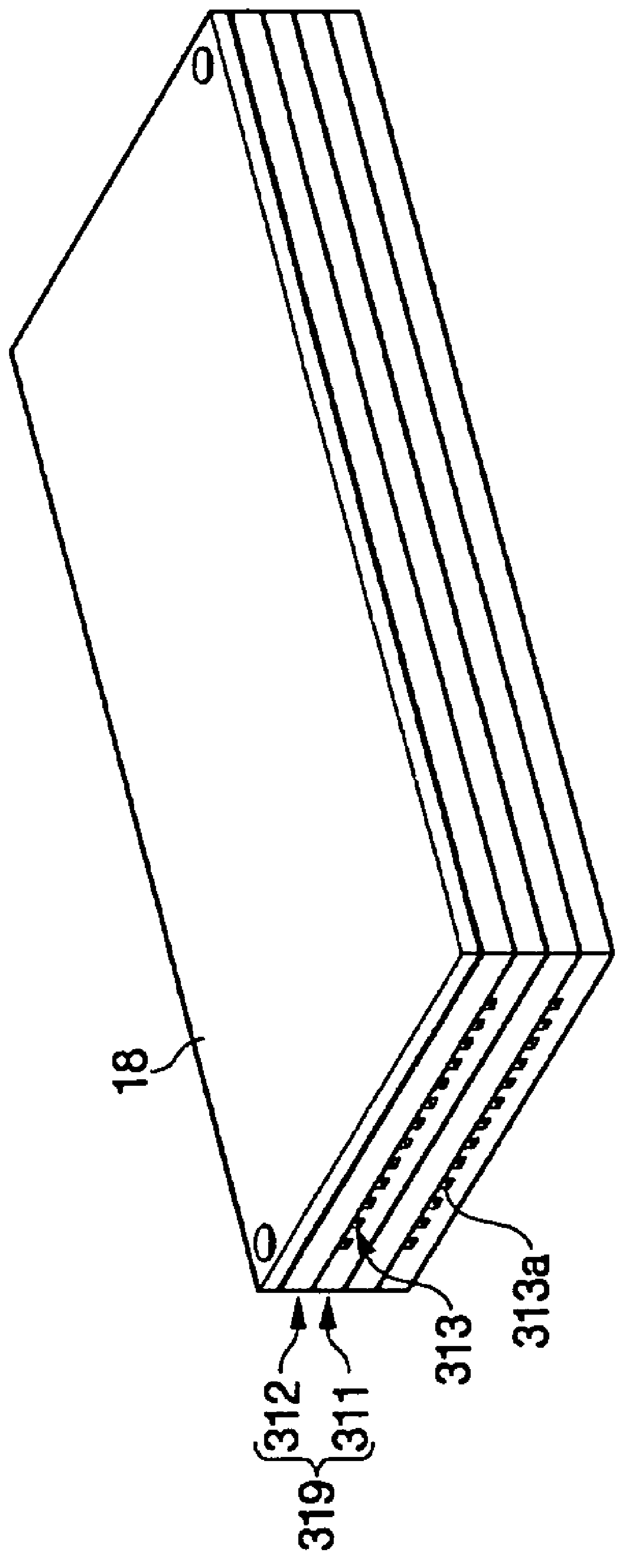
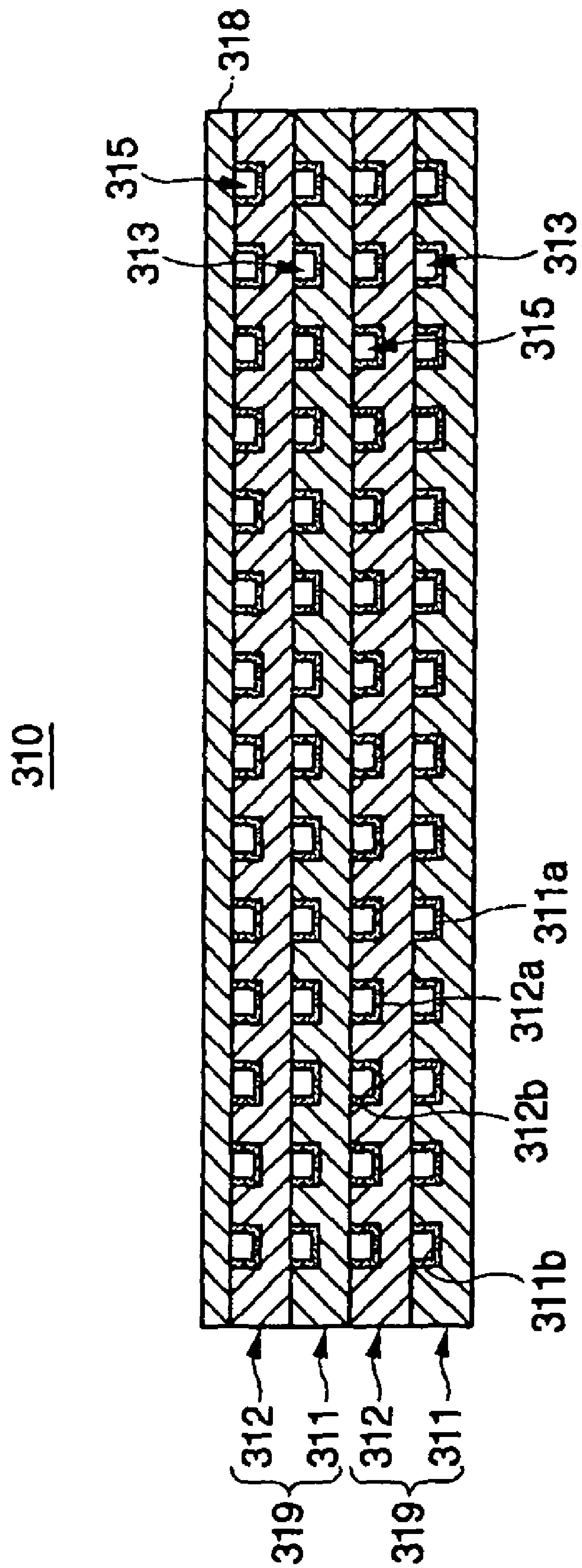


FIG. 7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318
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311a
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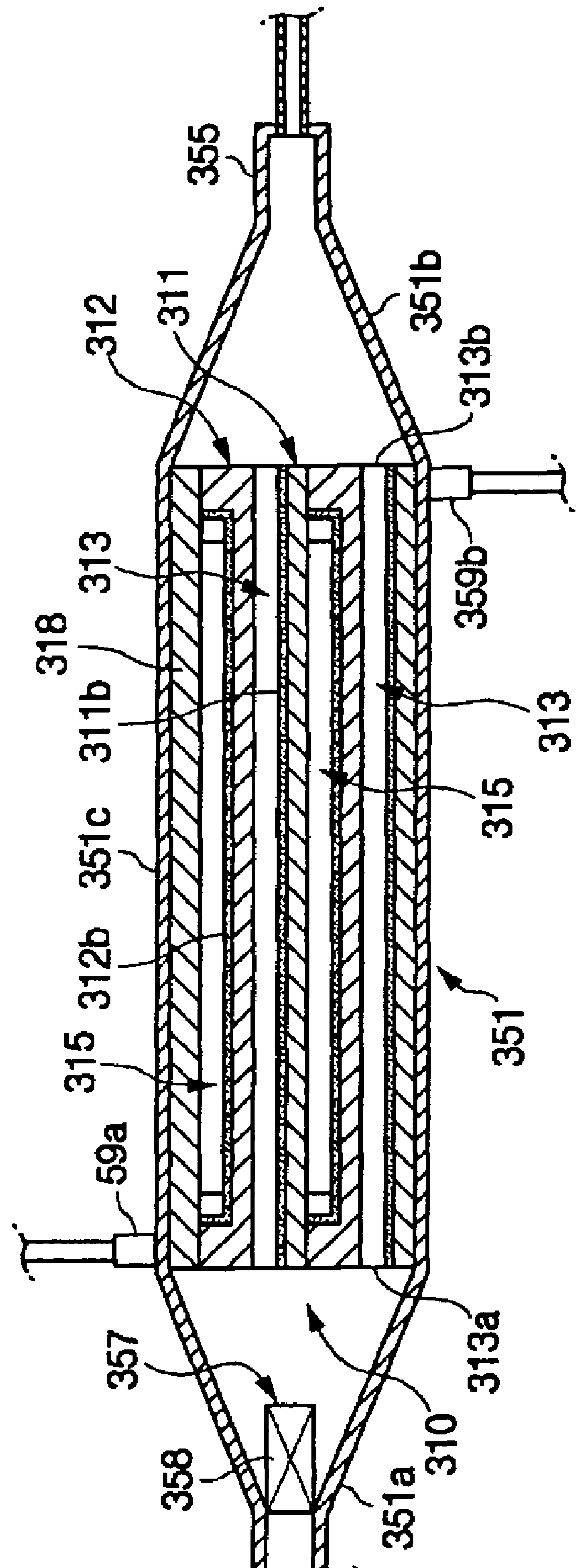
FIG. 8

300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351a
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FUEL REFORMER

CROSSED-REFERENCES TO RELATED APPLICATIONS

This application claims priority to and the benefit of Korean Patent Application No. 10-2005-0089814, filed on Sep. 27, 2005, and Korean Patent Application No. 10-2006-0010566, filed on Feb. 3, 2006, in the Korean Intellectual Property Office, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fuel reformer, and more particularly, to a fuel reformer for generating thermal energy through an oxidation reaction of a fuel.

2. Description of the Related Art

A fuel cell is constructed as a system for generating electric energy using a fuel.

In the fuel cell, a polymer electrolyte membrane fuel cell has an excellent output characteristic, a low operating temperature, and fast starting and response characteristics. In addition, the polymer electrolyte fuel cell advantageously has a wide range of applications including a mobile power source for vehicles, a distributed power source for home or buildings, and a small-sized power source for electronic apparatuses.

The fuel cell system employing the polymer electrolyte membrane fuel cell includes a fuel cell main body, which can also be referred to as a stack, a fuel reformer which reforms the fuel to generate a reforming gas containing hydrogen and supplies the reforming gas to the fuel cell main body, and an oxidant gas supply unit which supplies an oxidant gas to the stack.

Therefore, the polymer electrolyte membrane fuel cell system generates electric energy in the stack through an electrochemical reaction between the reforming gas supplied from the fuel reformer and the oxidant gas supplied from the oxidant gas supply unit.

The fuel cell reformer may include a heat source which generates thermal energy by oxidizing a fuel using an oxidation catalyst and a reforming reaction unit which generates the reforming gas through a reforming reaction of the fuel using the thermal energy.

Here, the heat source can generate the thermal energy by oxidizing a liquid fuel such as methanol and ethanol or a gaseous fuel such as LPG and LNG. Particularly, the heat source using the liquid fuel can generate the thermal energy in a certain (or predetermined) temperature range through the oxidation reaction of the fuel using the oxidation catalyst even at room temperature.

On the other hand, because the heat source cannot generate the oxidation reaction of the gaseous fuel using the oxidation catalyst at room temperature, when a conventional fuel reformer includes the heat source that oxidizes a gaseous fuel, an additional preheater is needed for preheating the oxidation catalyst to a certain (or predetermined) temperature to enable an oxidation reaction of the gaseous fuel.

In addition, a conventional fuel reformer includes a heat source that ignites and burns a liquid fuel; and because the energy efficiency of a fuel reformer is changed by the location of the heat source, and the heat source is oxidized by the flame, the durability of the heat source deteriorates as a result.

Thus, the heat source has to be frequently replaced, thereby reducing the lifespan of the fuel reformer.

SUMMARY OF THE INVENTION

An aspect of the present invention provides a fuel reformer capable of generating thermal energy through an oxidation reaction using an oxidation catalyst by preheating the oxidation catalyst by igniting and burning a fuel when a fuel cell system is initially driven.

An embodiment of the present invention provides a fuel reformer including: a first pipe; a second pipe disposed in the first pipe; a main heat source including an oxidation catalyst in the second pipe and adapted to generate thermal energy within a reforming temperature range through an oxidation reaction of a fuel using the oxidation catalyst; an auxiliary heat source including a torch connected to the second pipe to ignite and burn the gaseous fuel to preheat the oxidation catalyst to within a reaction starting temperature range; and a reforming reaction unit including a reforming catalyst in a region of a space between the first and second pipes and adapted to generate a reforming gas containing hydrogen through the reforming reaction of the fuel using the reforming catalyst by using the thermal energy generated by the main heat source.

In the above embodiment of the present invention, the fuel reformer may further include a carbon monoxide reduction unit constructed by filling another region of the space between the first and second pipes with a water gas shift catalyst to reduce a concentration of carbon monoxide contained in the reforming gas.

In addition, the fuel reformer may further include a barrier disposed between the first and second pipes to partition the space between the first and second pipes into the region filled with the reforming catalyst and the another region filled with the water gas shift catalyst.

In addition, the barrier may have a mesh shape.

In addition, the reaction starting temperature range of the oxidation catalyst may be from about 150° C. to about 300° C.

In addition, the reforming temperature range of the thermal energy generated by the main heat source may be from about 600° C. to about 700° C.

According to another embodiment of the present invention, a fuel reformer is provided to include: a reactor body including a plurality of reaction substrates (or plates) that generate thermal energy through an oxidation reaction of a first reactant including a fuel and generate a reforming gas through a reforming reaction of a second reactant including the fuel; and a preheating unit disposed in the reactor body to ignite and burn the first reactant in order to preheat the reactor body.

In the above embodiment of the present invention, the preheating unit may include: a housing for enclosing the reactor body and a burner disposed in the housing to ignite and burn the first reactant external to the reactor body.

Another embodiment of the present invention provides a fuel reformer including: one or more first reaction substrates including a plurality of first channels for allowing a first reactant including a fuel to flow and an oxidation catalyst layer formed on a surface of the first channels; one or more second reaction substrates including a plurality of second channels for allowing a second reactant including the fuel to flow and a reforming catalyst layer formed on a surface of the second channel or channels; a reactor body constructed by adhering one of the first reaction substrates to one of the second reaction substrates; and a preheating unit disposed in the reactor body to ignite and burn the first reactant in order to preheat the oxidation catalyst layer in a reaction starting temperature range.

In the above embodiment of the present invention, the reactor body may include one or more unit bodies, each of the unit bodies being constructed by adhering one of the first reaction substrates to one of the second reaction substrates.

In addition, the reactor body may include a cover plate adhered to the second reaction substrate of one of the unit bodies.

In addition, the reactor body may be constructed by successively adhering the unit bodies to one another.

In addition, the reactor body may include a cover plate adhered to a top most one of the second reaction substrates disposed at the top of the reactor body.

In addition, the preheating unit may include: a housing for enclosing the reactor body and a burner disposed in the housing to ignite and burn the first reactant external to the reactor body.

In addition, the housing may include: a first portion having a horn shape located at a first end portion of the reactor body; a second portion having a horn shape located at a second end portion of the reactor body; and a third portion adhered to the reactor body with the exception of the first end portion of the reactor body and the second end portion of the reactor body.

In addition, the reactor body may include a path constructed by using the first channels and the adhered surface of the second reaction substrate to allow the first reactant to flow, and the path may include a plurality of injection holes formed at a first end portion of the reactor body and a plurality of discharging holes formed at a second end portion of the reactor body connected with the injection holes.

In addition, the preheating unit may include: a housing for enclosing the reactor body and a burner unit disposed in the housing to ignite and burn the first reactant to spray (or inject) a flame to the injection holes.

In addition, the housing may include: a first portion having a horn shape located at a side of the injection holes; a second portion having a horn shape located at a side of the discharging holes; and a third portion adhered to the reactor body with the exception of the first end portion of the reactor body and the second end portion of the reactor body.

In addition, the burner may be disposed in the first portion.

In addition, in the housing, an injection hole for injecting the first reactant into the first portion may be formed in the first portion, and a discharging hole for discharging a combustion gas of the first reactant burned by the burner and a reaction gas of the first reactant oxidized by the oxidation catalyst layer may be formed in the second portion.

In addition, the reaction starting temperature range of the oxidation catalyst layer may be from about 150° C. to about 300° C.

In addition, the first reaction substrate may generate thermal energy with a temperature range (or a reforming temperature range) from about 600° C. to about 700° C. through the oxidation reaction of the first reactant.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, together with the specification, illustrate exemplary embodiments of the present invention, and, together with the description, serve to explain the principles of the present invention.

FIG. **1** is a perspective view illustrating a fuel reformer according to a first embodiment of the present invention.

FIG. **2** is a cross sectional view of the fuel reformer shown in FIG. **1**.

FIG. **3** is a cross sectional view of a fuel reformer according to a second embodiment of the present invention.

FIG. **4** is a perspective view illustrating a fuel reformer according to a third embodiment of the present invention.

FIG. **5** is an exploded perspective view of a reactor body of the fuel reformer shown in FIG. **4**.

FIG. **6** is a perspective view showing a structure in which the reactor body shown in FIG. **4** is combined.

FIG. **7** is a longitudinal cross sectional view of the reactor body shown in FIG. **6**.

FIG. **8** is a transverse cross sectional view of the fuel reformer shown in FIG. **4**.

DETAILED DESCRIPTION

In the following description, only certain exemplary embodiments of the present invention are shown and described, by way of illustration. As those skilled in the art would recognize, the described exemplary embodiments may be modified in various ways, all without departing from the spirit or scope of the present invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not restrictive.

FIG. **1** is a perspective view illustrating a fuel reformer **100** according to a first embodiment of the present invention. FIG. **2** is a cross sectional view of the fuel reformer **100** shown in FIG. **1**.

Referring to FIGS. **1** and **2**, the fuel reformer **100** has a structure for burning a gaseous fuel such as LPG or LNG, or a butane gas, to generate thermal energy and to generate a reforming gas containing hydrogen through a reforming reaction of the gaseous fuel using thermal energy.

The fuel cell reformer **100** is used for a fuel cell system employing the polymer electrolyte membrane fuel cell which generates electrical energy through an oxidation reaction of the reforming gas and a reduction reaction of an oxidant gas. Therefore, the fuel cell reformer **100** has a function of supplying the reforming gas to a stack of the polymer electrolyte membrane fuel cell system.

The fuel reformer **100** includes a main heat source **10** for generating thermal energy with a certain (or predetermined) temperature range through an oxidation reaction of the gaseous fuel using an oxidation catalyst **11**, an auxiliary heat source **20** for preheating the oxidation catalyst **11** of the main heat source **10** within a reaction starting temperature range, and a reforming reaction unit **30** for generating a reforming gas containing hydrogen through the reforming reaction of the gaseous fuel by a reforming catalyst **31** using the thermal energy generated by the main heat source **10**.

The fuel reformer **100** includes a reformer main body **50** having a shape of a concentric double pipe. The reformer main body **50** includes a first pipe **51** and a second pipe **52** that is located in the first pipe **51**.

The first pipe **51** has a cylindrical shape which has a certain (or predetermined) cross sectional area and substantially closed ends. The second pipe **52** has a cylindrical shape which has a cross sectional area smaller than that of the first pipe **51** and substantially closed ends. The first and second pipes **51** and **52** are disposed along an axial direction (a concentric axial direction) of the first pipe **51** so that an outer surface of the second pipe **52** is separated by a certain (or predetermined) interval from an inner surface of the first pipe **51**.

In the fuel reformer **100**, according to an embodiment, the main heat source **10** is used for generating thermal energy needed for the reforming reaction of the reforming reaction unit **30** and for supplying the thermal energy to the reforming reaction unit **30**. The main heat source **10** generates the thermal energy for maintaining a temperature range (or a reforming temperature range) of from about 600° C. to about 700° C. needed for the reforming reaction of the reforming reaction unit **30**.

The main heat source **10** is generated by filling the inner space of the second pipe **52** with the oxidation catalyst **11** to cause an oxidation reaction between the gaseous fuel and air using the oxidation catalyst **11** which results in the generation the thermal energy that is within the aforementioned temperature range.

The oxidation catalyst **11** is used for precipitating the oxidation reaction between the gaseous fuel and air. The oxidation catalyst **11** may have a structure where a catalytic material such as platinum (Pt) and/or ruthenium (Ru) is contained in a pellet-shaped carrier made of alumina (Al2O3), silica (SiO2), and/or titania (TiO2).

In the main heat source **10**, a first injection hole **13** through which the gaseous fuel and air are injected into the second pipe is disposed at an end portion of the second pipe **52**.

In addition, in the main heat source **10**, a first discharging hole **15** for discharging the combustion gas generated by burning the gaseous fuel and air through the oxidation reaction between the gaseous fuel and air is disposed at the other end portion of the second pipe **52**.

According to the present embodiment, the auxiliary heat source **20** is used for preheating the oxidation catalyst **11** of the main heat source **10** to within the reaction starting temperature range, when the fuel reformer **100** is initially driven.

The auxiliary heat source **20** generates the thermal energy for preheating the oxidation catalyst **11** of the main heat source **10** to within a temperature range of from about 150° C. to about 300° C., which is needed for starting the reaction, by igniting and burning gaseous fuel and air.

Because the oxidation catalyst **11** of the main heat source **10** cannot generate the oxidation reaction between the gaseous fuel and air at room temperature, when the fuel reformer **100** is initially driven, the oxidation catalyst **11** of the main heat source **10** is preheated by the auxiliary heat source **20** in order to supply thermal energy (with a temperature range in which the oxidation reaction between the gaseous fuel and air starts) to the oxidation catalyst **11** of the main heat source **10**.

In one embodiment, the auxiliary heat source **20** includes a torch **21** connected to an end portion of the second pipe **52**. The torch **21** has a function of igniting and burning the gaseous fuel together with air in the second pipe **52**.

The torch **21** includes a suitable igniter plug (not shown) for igniting the gaseous fuel and the air.

In addition, in the auxiliary heat source **20**, a second injection hole **23** for injecting the gaseous fuel and the air into the second pipe **52** is formed at the torch **21**. The combustion gas generated when the gaseous fuel and air are ignited and burned in the second pipe **52** is discharged through the first discharging hole **15** of the aforementioned main heat source **10**.

In an embodiment of the present invention, the reforming reaction unit **30** is constructed by filling the space between the first and second pipes **51** and **52** with the reforming catalyst **31**, and accordingly, the reforming gas containing hydrogen is generated through the reforming reaction of the gaseous fuel using the reforming catalyst **31**.

Here, the reforming reaction unit **30** has a structure of generating a reforming gas containing hydrogen from the fuel through a catalyst reaction such as a steam reforming reaction, a partial oxidation reaction, an auto-thermal reaction, and/or a steam reforming reaction between the fuel and water using thermal energy.

In the reforming reaction unit **30**, the reforming catalyst **31** may have a structure where a catalytic material such as copper (Cu), nickel (Ni), and/or platinum (Pt) is contained in a pellet-shaped carrier made of alumina (Al2O3), silica (SiO2), and/or titania (TiO2).

In addition, in the reforming reaction unit **30**, a third injection hole **33** for injecting the gaseous fuel and water into the space between the first and second pipes **51** and **52** is formed at an end portion of the first pipe **51**.

In addition, in the reforming reaction unit **30**, a second discharging hole **35** for discharging the reforming gas generated through the reforming reaction between the gaseous fuel and water steam using the reforming catalyst **31** in the space between the first and second pipes **51** and **52** is formed at the other end portion of the first pipe **51** from the portion where the injection hole **33** is formed.

Here, the second discharging hole **35** may be connected to the stack of the polymer electrolyte membrane fuel cell, mentioned above, through a suitable pipe line.

In an embodiment, the reforming reaction unit **30** generates the reforming gas containing hydrogen through the reforming reaction between the gaseous fuel and the water steam using the reforming catalyst **31**, but the present invention is not thereby limited. The reforming reaction unit **30** may generate the reforming gas through the reforming reaction between a liquid fuel such as methanol and ethanol and the water steam.

Now, a method of driving the fuel reformer **100** according to an embodiment of the present invention will be described in more detail.

Still referring to FIGS. **1** and **2**, first, when the fuel reformer **100** is initially driven, the gaseous fuel and the air are supplied into the second pipe **52** through the second injection hole **23** of the auxiliary heat source **20** that contains the torch **21**.

In this state, the igniter plug (not shown) of the torch **21** ignites the air and the gaseous fuel injected into the second pipe **52**. Then, the auxiliary heat source **20** generates a certain (or predetermined) amount of thermal energy and supplies the thermal energy to the oxidation catalyst **11** of the main heat source **10**. Accordingly, the oxidation catalyst **11** of the main heat source **10** is preheated to within a reaction starting temperature range of from about 150° C. to about 300° C.

Subsequently, when the fuel reformer **100** is normally driven, a supply of the gaseous fuel and air to be supplied into the second pipe **52** through the second injection hole **23** of the torch **21** is stopped by the operation of a suitable valve (not shown).

When the fuel reformer **100** is normally driven, the gaseous fuel and the air are supplied into the second pipe **52** through the first injection hole **13** of the main heat source **10**. Then, the main heat source **10** generates the thermal energy for maintaining the certain (or predetermined) temperature range (or the reforming temperature range) of from about 600° C. to about 700° C., which is needed for the reforming reaction in the reforming reaction unit **30**, through the oxidation reaction between the gaseous fuel and the air using the preheated oxidation catalyst **11**. Accordingly, the thermal energy maintaining the aforementioned temperature range is supplied to the reforming catalyst **31** of the reforming reaction unit **30** through the second pipe **52**.

After the aforementioned procedures, the gaseous fuel and the water are supplied to the space between the first and second pipes **51** and **52** through the third injection hole **33** of the reforming reaction unit **30**. Then, the reforming reaction unit **30** absorbs the thermal energy generated by the main heat source **10**, and a steam reforming reaction between the gaseous fuel and water using the reforming catalyst **31** is performed, thereby generating the reforming gas containing hydrogen.

Accordingly, since the reforming gas is discharged through the second discharging hole **35** of the reforming reaction unit **30** and supplied to the stack, an oxidation reaction of the hydrogen contained in the reforming gas and a reduction reaction of the separately supplied air are performed in the stack to generate a certain (or predetermined) output of electric energy.

FIG. **3** is a cross sectional view of a fuel reformer **200** according to a second embodiment of the present invention.

Referring to FIG. **3**, the fuel reformer **200** further includes a carbon monoxide reduction unit **170** for reducing a concentration of carbon monoxide contained in the reforming gas generated by a reforming reaction unit **130**.

Since, like the aforementioned embodiment, the fuel reformer **200** includes a main heat source **110** and an auxiliary heat source **120**, and the main heat source **110** and the auxiliary heat source **120** have substantially the same structures as those of the aforementioned embodiment of FIGS. **1** and **2**, the detailed description thereof is omitted.

In the embodiment of FIG. **3**, when the space between the first and second pipes **151** and **152** is partitioned into first and second regions A and B, the reforming reaction unit **130** is constructed by filling the first region A with a reforming catalyst **131**.

The first and second regions A and B are partitioned by a barrier **180** having a mesh shape. The barrier **180** includes a plurality of holes **181** and has the shape of a ring where the second pipe **152** passes through a central portion thereof. In addition to the function of partitioning the inner space between the first and second pipes **151** and **152** into the first and second regions A and B, the barrier **180** has a function of allowing the reforming gas generated by the reforming reaction unit **130** to flow into the carbon monoxide reduction unit **170**, described in more detail below, through the aforementioned holes **181**.

In addition, according to this embodiment, in the reforming reaction unit **130**, an injection hole **133** for injecting the gaseous fuel and the water into the first region A is formed at an end portion of the first pipe **151**.

In this embodiment, the carbon monoxide reduction unit **170** is constructed by filling the second region B between the first and second pipes **151** and **152** with a water gas shift catalyst **171**.

The water gas shift catalyst **171** precipitates the water gas shift reaction of carbon monoxide contained in the reforming gas to reduce the concentration of carbon monoxide. The water gas shift catalyst **171** may be constructed by containing a catalytic material such as copper (Cu), zinc (Zn), iron (Fe), and/or chromium (Cr) in a pellet-shaped carrier made of alumina (Al2O3), silica (SiO2), and/or titania (TiO2).

In the carbon monoxide reduction unit **170**, a discharging hole **173** for discharging the reforming gas, of which the concentration of carbon monoxide is reduced, from the second region B is formed at the other end portion of the first pipe **151** from the injection hole **133**. The discharging hole **173** may be connected to the stack (not shown) of the polymer electrolyte membrane fuel cell, mentioned above, through a suitable pipe line.

In a method of driving the fuel reformer **200** according to this embodiment of the present invention, when the reforming gas is generated by the reforming reaction unit **130** as in the aforementioned embodiment of FIGS. **1** and **2**, the reforming gas is further supplied to the carbon monoxide reduction unit **170** (that is the second region B between the first and second pipes **151** and **152**) through the holes **181** of the barrier **180**.

Accordingly, in the carbon monoxide reduction unit **170**, additional hydrogen is concentrated (or generated) through the water gas shift reaction of the carbon monoxide contained in the reforming gas using the water gas shift reaction catalyst **171**, and the concentration of carbon monoxide is reduced at the same time. The reforming gas in which the concentration of carbon monoxide has been reduced is discharged through the discharging hole **173** of the carbon monoxide reduction unit **170** and supplied to the stack.

Since other components and operations of the fuel reformer **200** according to this embodiment are substantially the same as those of the aforementioned fuel cell reformer **100** referred to in FIGS. **1** and **2** according to the first embodiment, detailed description thereof is omitted.

FIG. **4** is a perspective view illustrating a fuel reformer **300** according to a third embodiment of the present invention.

Referring to FIG. **4**, the fuel reformer **300** generates thermal energy with a certain (or predetermined) temperature range through the oxidation reaction between the gaseous fuel and the air (hereinafter also referred to as "first reactants"). The fuel reformer **300** includes a reactor body **310** in which the reforming gas is generated through the reforming reaction between the gaseous fuel and the water (hereinafter also referred to as "second reactants") using the thermal energy.

FIG. **5** is an exploded perspective view of a reactor body **310** of the fuel reformer **300** shown in FIG. **4**. FIG. **6** is a perspective view showing a structure in which the reactor body **310** shown in FIG. **4** is combined. FIG. **7** is a longitudinal cross sectional view of the reactor body **310** shown in FIG. **4**.

Referring to FIGS. **5** to **7**, the reactor body **310**, according to the third embodiment, includes a first reaction substrate (or plate) **311** provided with a first channel **311*a*** for allowing the first reactant to flow on a surface thereof and a second reaction substrate **312** provided with a second channel **312*a*** for allowing the second reactant to flow on a surface thereof.

Here, the first and second reaction substrates **311** and **312** are rectangular plates with certain (or predetermined) width and length and are made of metal such as aluminum, stainless steel, copper, nickel, and/or iron having a relatively high thermal conductivity.

The first reaction substrate **311** is used to generate thermal energy with a certain (or predetermined) temperature range (a temperature range needed for the reforming reaction of the reactant) of from about 600° C. to about 700° C. through the oxidation reaction of the first reactants and supply the thermal energy to the second reaction substrate **312**.

The first reaction substrate **311** includes the plurality of first channels **311*a*** on an upper surface thereof. The first channels **311*a*** may be formed by using a plurality of ribs that protrude from the upper surface of the first reaction substrate **311**.

Then, the first channels **311*a*** have a groove shape that is connected from an end portion of the first reaction substrate **311** to the other end portion thereof. Then, a suitable oxidation catalyst layer **311*b*** for precipitating the oxidation reaction of the first reactant is formed on the surface of the first channels **311*a***.

The second reaction substrate **312** is used to receive thermal energy from the first reaction substrate **311** and generate the reforming gas containing hydrogen through the reforming reaction of the second reactant using the thermal energy.

The second reaction substrate **312** is adhered to the first reaction substrate **311** and includes the second channels **312*a*** on the upper surface thereof. The second channels **312***a* may be formed by using a plurality of ribs that protrude from the upper surface of the second reaction substrate **312**.

The second channels **312***a* have a groove (and serpentine) shape that is connected to a pair of manifolds **312***c* located in the diagonal direction.

Then, a suitable reforming catalyst layer **312***b* for precipitating the reforming reaction of the second reactant is formed on the surface of the second channel **312***a*.

In the third embodiment, a unit body (or body unit) **319** is constructed by adhering the lower surface of the second reaction substrate **312** to the upper surface of the first reaction substrate **311**. The reactor body **310** may be constructed by sequentially adhering the unit bodies **319** to one another. Then, a cover plate **318** is adhered to the upper surface of the second reaction substrate **312** located at the top of the reactor body **310**.

Alternatively, the reactor body **310** may include a single unit body **319**. Then, the cover plate **318** is adhered to the upper surface of the second reaction substrate **312** that is the upper surface of the unit body **319**.

Here, the first and second reaction substrates **311** and **312**, and the cover plate **318** are adhered to one another by using a suitable bonding member such as a bolt and a nut or by using a suitable bonding method such as welding and/or brazing methods.

Accordingly, in the reactor body **310**, the first and second reaction substrates **311** and **312** are adhered to each other to form first paths **313** constructed by using the first channels **311***a* of the first reaction substrate **311** and the adhered surface of the second reaction substrate **312** for allowing the first reactant to flow.

Then, since the first channels **311***a* are connected from an end portion of the first reaction substrate **311** to the other end portion thereof, the first paths **313** include a plurality of injection holes **313***a* that are openings located at an end portion of the reactor body **310** and a plurality of discharging holes **313***b* (referring to FIG. **8**) that are openings located at the other end portion thereof.

In addition, in the reactor body **310**, the lower surface of the first reaction substrate **311** is adhered to the upper surface of the second reaction substrate **312**, and the cover plate **318** is adhered to the upper surface of the second reaction substrate located at the top of the reactor body **310** to form second paths **315** (constructed by using the second channels **312***a* and the adhered surface of the cover plate **318**) which allow the second reactant to flow.

Because the oxidation catalyst layer **311***b* of the first reaction substrate **311** cannot oxidize the first reactant at room temperature, when the fuel reformer **300** having the aforementioned structure is initially driven, the oxidation catalyst layer **311***b* needs to be preheated to within the temperature range in which the oxidation reaction of the first reactant starts.

As shown in FIG. **4**, the fuel reformer **300** includes a preheating unit **350** for preheating the reactor body **310** by igniting and burning the first reactant.

FIG. **8** is a transverse cross sectional view of FIG. **4**. Referring to FIG. **8**, when the fuel reformer **300** is initially driven, the preheating unit **350** ignites and burns the first reactant, and supplies the thermal energy caused by burning the first reactant to the first reaction substrate **311**, thereby preheating the oxidation catalyst layer **311***b* of the first reaction substrate **311** to within the reaction starting temperature range of from about 150° C. to about 300° C.

Specifically, the preheating unit **350** includes a housing **351** for enclosing the reactor body **310** and a burner **357**, which is located in the housing **351**, for igniting and burning the first reactant at the outside of the reactor body **310**.

In the present embodiment, the housing **351** is a case for enclosing the reactor body **310** and is made of a suitable heat insulating material to prevent the thermal energy from being released out of the housing **351**.

In the housing **351**, a first portion **351***a* having a horn shape is formed at an end portion of the reactor body **310**, a second portion **351***b* having a horn shape is formed at the other end portion of the reactor body **310**, and a third portion **351***c* is adhered to the reactor body **310** except at the end portions.

Since the first portion **351***a* is integrated into one side of the third portion **351***c*, the first portion **351***a* has a shape of which the cross section decreases from a side of the third portion **351***c* so that a certain (or predetermined) inner space is formed at the end portion of the reactor body **310** at which the injection hole **313***a* of the first path **313** is formed.

Since the second portion **351***b* is formed at the other end of the third portion **351***c*, the second portion **351***b* has a shape of which the cross section decreases from the other side of the third portion **351***c* so that a certain (or predetermined) inner space is formed at the other end portion of the reactor body **310** at which the discharging hole **313***b* of the first path **313** is formed.

The first portion **351***a* has a horn shape in order to diffuse the first reactant, which is injected into the inner space of the first portion **351***a* through the first injection hole **353**, described in more detail below, in the direction in which the cross section of the first portion **351***a* increases and inject the first reactant into the injection hole **313***a* of the first path **313**.

In addition, the second portion **351***b* has the horn shape in order to easily discharge the combustion gas and the reaction gas through the first discharging hole **355** (described in more detail below) by collecting the combustion gas of the first reactant, which is generated by burning the first reactant using the burner **357** (described in more detail below), injected into the first path **313** through the injection hole **313***a* of the first path **313**, and discharged through the discharging hole **313***b* of the first path **313**, and the reaction gas of the first reactant, which is injected into the first path **313** through the injection hole **313***a* of the first path **313**, oxidized by the oxidation catalyst layer **311***b*, and discharged through the discharging hole **313***b* of the first path **313**.

In the aforementioned housing **351**, the first injection hole **353** for injecting the first reactant into the inner space of the first portion **351***a* is formed in the first portion **351***a*.

The first injection hole **353** is formed in the pointed portion of the first portion **351***a*. In addition, the first discharging hole **355** for discharging the combustion gas of the first reactant burned by the burner **357** and the reaction gas of the first reactant oxidized by the oxidation catalyst layer **311***b* of the first reaction substrate **311** is formed in the second portion **351***b*. The first discharging hole **355** is formed in the pointed portion of the second portion **351***b*.

As described above, the burner **357** includes a torch **358**, which is disposed in the first portion **351***a* and connected to the first injection hole **353**, for igniting and burning the first reactant that is injected into the inner space of the first portion **351***a* through the first injection hole **353**.

The torch **358** includes an igniter plug (not shown) for igniting the first reactant. The igniter plug is a suitable igniter plug controlled by an additional controller (not shown) to generate a flame.

Also, FIG. **8** shows a second injection hole **59***a* for injecting the second reactant into the second path **315** of the reactor body **310**, and a second discharging hole **359***b* for discharging the reforming gas generated when the second reactant passing through the second path **315** generates the reforming reaction using the reforming catalyst layer **312***b*.

The aforementioned second injection hole **59***a* and the second discharging hole **359***b* are connected to the manifold **312***c* of the second reaction substrate **312** shown in FIG. **5**.

A method of driving the fuel reformer **300** having the aforementioned structure will be described in more detail below.

When the fuel reformer **300** is initially driven, the first reactant is injected into the inner space of the first portion **351***a* through the first injection hole **353** of the housing **351**.

The igniter plug (not shown) of the torch **358** generates a flame to ignite the first reactant injected into the inner space of the first portion **351***a*. Then, the first reactant is burned in the inner space of the first portion **351***a* to generate the certain (or predetermined) thermal energy.

Accordingly, a high temperature combustion gas generated by burning the first reactant is injected into the first path **313** through the injection hole **313***a* of the first path **313** to flow along the first path **313** and discharged through the discharging hole **313***b* of the first path **313**, thereby supplying the thermal energy to the oxidation catalyst layer **311***b* of the first reaction substrate **311**.

The oxidation catalyst layer **311***b* of the first reaction substrate **311** is preheated to within the reaction starting temperature range (from about 150° C. to about 300° C.) in which the oxidation reaction of the first reactant starts.

Then, the combustion gas discharged through the discharging hole **313***b* of the first path **313** is collected in the inner space of the second portion **351***b* and discharged out of the housing **351** through the first discharging hole **355**.

Subsequently, when the fuel reformer **300** is normally driven, since the first reactant is continuously supplied to the inner space of the first portion **351***a* through the first injection hole **353** of the housing **351**, the igniter plug is controlled by the controller to not operate.

When the fuel reformer **300** is normally driven, the first reactant is injected from the inner space of the first portion **351***a* into the first path **313** through the injection hole **313***a* of the first path **313**. Then, in the first reaction substrate **311**, the first reactant flowing along the first path **313** is oxidized by using the oxidation catalyst layer **311***b* to generate the thermal energy for maintaining the certain (or predetermined) temperature range (or reforming temperature range) of from about 600° C. to about 700° C. needed for the reforming reaction of the second reactant.

Here, since the first reaction substrate **311** is adhered to the second reaction substrate **312**, the thermal energy is transferred to the second reaction substrate **312** through the first reaction substrate **311**, thereby being supplied to the reforming catalyst layer **312***b* of the second reaction substrate **312**.

The reaction gas of the first reactant oxidized by the oxidation catalyst layer **311***b* is discharged through the discharging hole **313***b* of the first path **313**, collected in the inner space of the second portion **351***b*, and discharged out of the housing **351** through the first discharging hole **355**.

After the aforementioned processes, the second reactant is supplied to the second path **315** of the reactor body **310** through the second injection hole **59***a*. Then, when the second reaction substrate **312** absorbs the thermal energy generated in the first reaction substrate **311**, the reforming reaction of the second reactant using the reforming catalyst layer **312***b* is performed to generate the reforming gas containing hydrogen.

Accordingly, since the reforming gas is discharged to the stack through the second discharging hole **359***b*, in the stack, the oxidation reaction of hydrogen contained in the reforming gas and a reduction reaction of separately supplied air are performed to output the certain (or predetermined) electric energy.

As described above, according to an embodiment of the present invention, since the fuel reformer includes the auxiliary heat source for preheating the oxidation catalyst by igniting and burning the fuel when the fuel reformer is initially driven, the fuel reformer can generate the thermal energy through the oxidation reaction of the fuel by using the oxidation catalyst when the fuel reformer normally operates.

Accordingly, since the oxidation catalyst is preheated by igniting and burning the fuel only when the fuel reformer is initially driven, the initial driving time of the fuel reformer is decreased, thereby improving energy efficiency of the fuel reformer, and the durability of the auxiliary heat source against a flame is improved, thereby increasing the lifetime of the fuel reformer.

While the invention has been described in connection with certain exemplary embodiments, it is to be understood by those skilled in the art that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications included within the spirit and scope of the appended claims and equivalents thereof.

What is claimed is:

1. A fuel reformer comprising:

a reactor body including a plurality of reaction substrates configured to generate thermal energy through an oxidation reaction of a first reactant including a fuel, the reactor body further being configured to generate a reforming gas through a reforming reaction of a second reactant including the fuel; and

a preheating unit configured to ignite and burn the first reactant in order to preheat the reactor body, the preheating unit comprising:

a housing enclosing the reactor body; and

a burner disposed in the housing to ignite and burn the first reactant external to the reactor body,

wherein the housing has:

a first injection hole located adjacent to the burner and configured to supply the second reactant to the plurality of reaction substrates; and

a second injection hole located adjacent to the burner and configured to supply the first reactant through the burner, and

wherein the reactor body has:

a third injection hole at a first side of the reactor body for injecting the burnt first reactant into the reactor body; and

a discharge hole at a second side of the reactor body for discharging the oxidized first reactant, the second side facing oppositely away from the first side.

2. The fuel reformer of claim **1**, wherein the third injection hole is located between the burner and the plurality of reaction substrates.

3. The fuel reformer of claim **1**, wherein the burner is located between the first injection hole and the second injection hole.

4. A fuel reformer comprising:

one or more first reaction substrates including a plurality of first channels for allowing a first reactant including a fuel to flow and in which an oxidation catalyst layer is formed on a surface of the first channels;

one or more second reaction substrates including a plurality of second channels for allowing a second reactant including the fuel to flow and a reforming catalyst layer fanned on a surface of the second channels;

a reactor body constructed by adhering one of the first reaction substrates to one of the second reaction substrates; and

a preheating unit configured to ignite and burn the first reactant in order to preheat the oxidation catalyst layer to within a reaction starting temperature range, the preheating unit comprising:

a housing for enclosing the reactor body; and

a burner disposed in the housing to ignite and burn the first reactant external to the reactor body,

wherein the housing has an injection hole adjacent to the burner,

wherein the injection hole is configured to supply the first reactant through the burner and to the plurality of reaction substrates, and

wherein the reactor body has:

a second injection hole at a first side of the reactor body for injecting the first reactant into the reactor body; and

a discharge hole at a second side of the reactor body for discharging a combustion gas of the first reactant, the second side facing oppositely away from the first side.

5. The fuel reformer of claim **4**, wherein the reactor body includes one or more unit bodies, each of the unit bodies being constructed by adhering one of the first reaction substrates to one of the second reaction substrates.

6. The fuel reformer of claim **5**, wherein the reactor body includes a cover plate adhered to the second reaction substrate of one of the unit bodies.

7. The fuel reformer of claim **5**, wherein the reactor body is constructed by successively adhering the unit bodies to one another.

8. The fuel reformer of claim **7**, wherein the reactor body includes a cover plate adhered to a top most one of the second reaction substrates disposed at the top of the reactor body.

9. The fuel reformer of claim **4**, wherein the housing comprises:

a first portion having a horn shape located at a first end portion of the reactor body;

a second portion having a horn shape located at a second end portion of the reactor body; and

a third portion adhered to the reactor body with the exception of the first end portion of the reactor body and the second end portion of the reactor body.

10. The fuel reformer of claim **9**, wherein the burner is disposed in the first portion.

11. The fuel reformer of claim **9**, wherein the housing comprises a discharging hole formed in the second portion and for discharging a combustion gas of the first reactant burned by the burner during start-up and for discharging a reaction gas of the first reactant oxidized by the oxidation catalyst layer after start-up.

12. The fuel reformer of claim **4**,

wherein the reactor body includes a path constructed by using the first channels and the adhered surface of the second reaction substrate to allow the first reactant to flow through, and

wherein the path includes a plurality of the second injection holes formed at a first end portion of the reactor body and a plurality of the discharging holes formed at a second end portion of the reactor body connected with the injection holes.

13. The fuel reformer of claim **4**, wherein the reaction starting temperature range of the oxidation catalyst layer is from about 150° C. to about 300° C.

14. The fuel reformer of claim **4**, wherein the first reaction substrate generates thermal energy with a temperature range from about 600° C. to about 700° C. through the oxidation reaction of the first reactant.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,017,088 B2
APPLICATION NO. : 11/528976
DATED : September 13, 2011
INVENTOR(S) : Sung-Chul Lee et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 12, Claim 4, line 67. Delete "fanned"
Insert -- formed --

Signed and Sealed this
Twenty-fourth Day of July, 2012

David J. Kappos
Director of the United States Patent and Trademark Office